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tain an abundant fossil fauna, largely of marine molluscs. The Saxicava formation includes beach gravels which are found at 27 different levels of general importance so far as the island is concerned. The highest of these is at an altitude of 617 feet above tide. Post-glacial movements are represented by minor faults and folds as well as by the continental deformation which altered the shore-lines of the Champlain sea. The latter is attributed to isostatic adjustment consequent upon the removal of the ice-load.

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SPECIAL ARTICLES

THE THEORY OF THE FREE-MARTIN

THE term free-martin is applied to the female of heterosexual twins of cattle. The recorded experience of breeders from ancient times to the present has been that such females are usually barren, though cases of normal fertility are recorded. This presents an uncomfortable case in twinning and sex-determination, and it has consequently been the cause of much speculation.

The appearance of an abstract in *SCIENCE*¹ of Leon J. Cole's paper before the American Society of Zoologists on "Twinning in Cattle with Special Reference to the Free-Martin," is the immediate cause of this preliminary report of my embryological investigation of the subject. Cole finds in a study of records of 303 multiple births in cattle that there were 43 cases homosexual male twins, 165 cases heterosexual twins (male and female), and 88 cases homosexual female, and 7 cases of triplets. This gives a ratio of about 1♂♂:4♂♀:2♀♀, for the twins instead of the expected ratio of 1:2:1. Cole then states:

The expectation may be brought more nearly into harmony with the facts if it is assumed that in addition to ordinary fraternal (dizygotic) twins, there are numbers of "identical" (monozygotic) twins of both sexes, and that while in the case of females these are both normal, in the case of a dividing male zygote, to form two individ-

uals, in one of them the sexual organs remain in the undifferentiated stage, so that the animal superficially resembles a female and ordinarily is recorded as such, although it is barren. The records for monozygotic twins accordingly go to increase the homosexual female and the heterosexual classes, while the homosexual male class in which part of them really belong, does not receive any increment.

Cole thus tentatively adopts the theory, which has been worked out most elaborately by D. Berry Hart, stated also by Bateson, and implied in Spiegelberg's analysis (1861), that the sterile free-martin is really a male co-zygotic with its mate.

Cole's figures represent the only statistical evidence that we have on this subject. Let us follow his suggestion and take from the heterosexual class enough cases to make the homosexual male twins equal in number to the homosexual female pairs; this will be approximately one fourth of the class, leaving the ratio 2:3:2 instead of 1:4:2. Which one of these is the more satisfactory sex ratio I leave others to determine; I wish only to point out the fatal objection, that, according to the hypothesis, the females remaining in the heterosexual class are normal; in other words, on this hypothesis the ratio of normal free-martins (females co-twin with a bull) to sterile ones is 3:1; and the ratio would not be very different on any basis of division of the heterosexual class that would help out the sex ratio. Hitherto there have been no data from which the ratio of normal to sterile free-martins could be computed, and Cole furnishes none. I have records of 21 cases statistically homogeneous, 3 of which are normal and 18 abnormal. That is, the ratio of normal to sterile free-martins is 1:6 instead of 3:1.

This ratio is not more adverse to the normals than might be anticipated, for breeders' associations will not register free-martins until they are proved capable of breeding, and some breeders hardly believe in the existence of fertile free-martins, so rare are they.

My own records of 41 cases of bovine twins (to date, February 25, 1916), all examined *in utero*, and their classification determined anatomically without the possibility of error,

¹ Vol. XLIII, p. 177, February 4, 1916.

give $14\sigma\sigma:21\sigma\phi:6\phi\phi$. It will be observed that this agrees with expectation to the extent that the sum of the homosexual classes is (almost) equal to the heterosexual class; and it differs from expectation inasmuch as the $\sigma\sigma$ class is over twice the $\phi\phi$ class instead of being equal to it, as it should be if males and females are produced in equal numbers in cattle. The material can not be weighted statistically because every uterus containing twins below a certain size from a certain slaughter house is sent to me for examination without being opened. Cole's material shows twice as many female as male pairs, and the heterosexual class is about one third greater than the sum of the two homosexual classes. I strongly suspect that it is weighted statistically; the possibility of this must be admitted, for the records are assembled from a great number of breeders. But, whether this is so or not, if we add the sterile free-martin pairs of my collection to the male side in accordance with Cole's suggestion, we get the ratio $32\sigma\sigma:3\sigma\phi:6\phi\phi$, which is absurd. And if we take Cole's figures, divide his heterosexual class into pairs containing sterile females and pairs containing normal females according to the expectation, 6 of the former to 1 of the latter, and add the former to his male class, we get an almost equally absurd result ($184\sigma\sigma:23\sigma\phi:88\phi\phi$). On the main question our statistical results are sufficiently alike to show that the free-martin can not possibly be interpreted as a male. The theory of Spiegelberg, D. Berry Hart, Bateson and Cole falls on the statistical side alone.

But the real test of the theory must come from the embryological side. If the sterile free-martin and its bull-mate are monozygotic, they should be included within a single chorion, and there should be but a single corpus luteum present. If they are dizygotic, we might expect two separate chorions and two corpora lutea. The monochorial condition would not, however, be a conclusive test of monozygotic origin, for two chorions originally independent might fuse secondarily. The facts as determined from examination of 41 cases are that about 97.5 per cent. of bovine twins are monochorial, but in spite of this nearly all

are dizygotic; for in all cases in which the ovaries were present with the uterus a corpus luteum was present in each ovary; in normal single pregnancies in cattle there is never more than one corpus luteum present. There was one homosexual case (males) in which only one ovary was present with the uterus when received, and it contained no corpus luteum. This case was probably monozygotic.

There is space only for a statement of the conclusions drawn from a study of these cases, and of normal pregnancies. In cattle a twin pregnancy is almost always a result of the fertilization of an ovum from each ovary; development begins separately in each horn of the uterus. The rapidly elongating ova meet and fuse in the small body of the uterus at some time between the 10 mm. and the 20 mm. stage. The blood vessels from each side then anastomose in the connecting part of the chorion; a particularly wide arterial anastomosis develops, so that either fetus can be injected from the other. The arterial circulation of each also overlaps the venous territory of the other, so that a constant interchange of blood takes place. If both are males or both are females no harm results from this; but *if one is male and the other female, the reproductive system of the female is largely suppressed, and certain male organs even develop in the female. This is unquestionably to be interpreted as a case of hormone action.* It is not yet determined whether the invariable result of sterilization of the female at the expense of the male is due to more precocious development of the male hormones, or to a certain natural dominance of male over female hormones.

The results are analogous to Steinach's feminization of male rats and masculinization of females by heterosexual transplantation of gonads into castrated infantile specimens. But they are more extensive in many respects on account of the incomparably earlier onset of the hormone action. In the case of the free-martin, nature has performed an experiment of surpassing interest.

Bateson states that sterile free-martins are found also in sheep, but rarely. In the four

twin pregnancies of sheep that I have so far had the opportunity to examine, a monochorial condition was found, though the fetuses were dizygotic; but the circulation of each fetus was closed. This appears to be the normal condition in sheep; but if the two circulations should anastomose, we should have the conditions that produce a sterile free-martin in cattle. The possibility of their occurrence in sheep is therefore given.

The fertile free-martin in cattle may be due to cases similar to those normal for sheep. Unfortunately when the first two cases of normal cattle free-martins that I have recorded, came under observation I was not yet aware of the significance of the membrane relations, and the circulation was not studied. But I recorded in my notebook in each case that the connecting part of the two halves of the chorion was narrow, and this is significant. In the third case the two chorions were entirely unfused; this case, therefore, constitutes an *experimentum crucis*. The male was 10.4 cm. long; the female 10.2 cm. The reproductive organs of both were entirely normal. The occurrence of the fertile free-martin is therefore satisfactorily explained.

The sterile free-martin enables us to distinguish between the effects of the zygotic sex-determining factor in mammals, and the hormonal sex-differentiating factors. The female is sterilized at the very beginning of sex-differentiation, or before any morphological evidences are apparent, and male hormones circulate in its blood for a long period thereafter. But in spite of this the reproductive system is for the most part of the female type, though greatly reduced. The gonad is the part most affected; so much so that most authors have interpreted it as testis; a gubernaculum of the male type also develops, but no scrotal sacs. The ducts are distinctly of the female type much reduced, and the phallus and mammary glands are definitely female. The general somatic habitus inclines distinctly toward the male side. Male hormones circulating in the blood of an individual zygotically female have a definitely limited influence, even though the action exists

from the beginning of morphological sex-differentiation. A detailed study of this problem will be published at a later date.

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A CHEMOTROPIC RESPONSE OF THE HOUSE FLY (*MUSCA DOMESTICA* L.)¹

It is generally conceded that the house fly lays its eggs most frequently in fermenting vegetable substances. Of these, fermenting horse manure is most often chosen, and about cities probably ninety per cent. or more of the house flies are bred from this substance.²

Although manure varies considerably, depending upon the food, the age and the health of the horse, it seems to be invariably attractive to female house flies, provided it is moist and not very old. The flies come to the manure primarily to lay their eggs, and although they may obtain some food from it, this is only a secondary object.

These general observations, together with some preliminary studies recently published,³ led me to believe that the house fly was allured to the manure pile by the odor of some volatile chemical substance which was liberated during the early stages of fermentation. Acting on this hypothesis, I have tested during the past summer the response of the house fly to a number of inorganic and organic compounds which occur as products of fermentation in barnyard manures.

This paper is a preliminary statement of the results of these experiments. A more detailed account will be given in another place.

Trap Experiments with Ammonia and Other Chemical Substances

The following chemical compounds were exposed in glass containers in screen-wire-fly

¹ This work was done in the department of entomology, New Jersey Agricultural College Experiment Station, and is published by permission of Dr. T. J. Headlee, entomologist of that station.

² Howard, L. O., "The House Fly—Disease Carrier," New York, 1911, p. 7.

³ 27th Ann. Rpt. N. J. Agr. College Exp. Station, 1914, pp. 396-399.